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(54) Display device.

(57) By choosing separate column voltages for the columns (4) associated with diffferent data $D_1 \ldots D_n$, a suitable choice of D_i/D_1 ($i = 2_1 \ldots n$) and the V_s/D_1 leads to a smaller reduction of the multiplex ratio as a result of voltage losses across the electrodes. Consequently a multiplex ratio can be used which is higher than that in the conventional method in which identical voltages are presented to all columns.

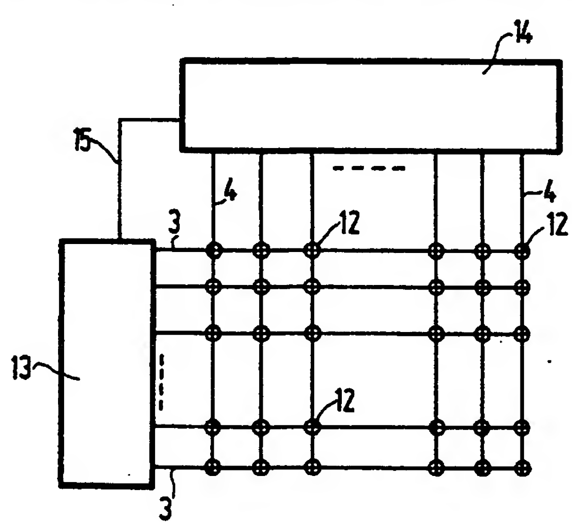

FIG. 2

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Display device.

The invention relates to a display device comprising a liquid crystalline material between two parallel support plates having surfaces facing each other, a pattern of row electrodes being provided on the one surface and a pattern of colum electrodes being provided on the other surface, the row electrodes crossing the column electrodes, thus constituting display elements at the area of the crossings, the device comprising a drive circuit for presenting data signals to be displayed to the column electrodes, and a row scanning circuit for scanning the row electrodes.

Display devices of this type are known and are usually operated in multiplex drive with electrical voltages in accordance with the so-called rms-mode. The drive mode is described by Alt & Pleshko in I.E.E.E. Trans. El. Dev., Vol. ED 21, 1974, pages 146-155 and is known as the most commonly used mode for driving liquid crystal display devices which are built up as a matrix of picture elements as described above and in which no active switches per picture element are used. The maximum number of rows N_{max} which can be driven with an acceptable contrast ratio by means of this mode is determined by the relation:

$$N_{max} = \left[\frac{\hat{V}^2_{on} + \hat{V}^2_{off}}{\hat{V}^2_{on} - \hat{V}^2_{off}}\right] = \left[\frac{S^2 + 1}{S^2 - 1}\right]^2 , \quad S = \frac{\hat{V}_{on}}{\hat{V}_{off}}$$

in which $\hat{V}_{on}$ represents the required rms voltage across a display element to switch it in on the "on"-condition and $\hat{V}_{off}$ represents the rms voltage at which the display cell is in the "off"-condition. As $\hat{V}_{on}$ and $\hat{V}_{off}$ are closer together, a larger number of rows can be driven. This of course requires a steep threshold in the transmission/voltage characteristic of the display element.

The rms voltages across the display elements do not naturally follow fom the selection- and data voltages presented. Due to the resistance of the electrodes voltage losses occur so that the voltage across the elements may be lower than is reuqired to cause them to switch. This leads to a decrease of the maximum number of rows to be multiplexed

A known solution to inhibit the effects of, for example, voltage losses across the row electrodes is that the selectin voltage is presented simultaneously to both ends of the row electrodes during a selection time t_s.

In patent application No. 11.868 simulataneously filed with this application a drive device with a different form of double drive is proposed (so-called "reversed scan").

In the present application the problem of voltage reduction due to resistance in the drive electrodes is solved in a completely different manner.

To this end a device according to the invention is characterized in that the drive circuit for a data signal to be displayed can present to a column electrode a voltage value dependent on the column electrode to be driven.

The invention is based on the recognition that the effective rms voltage acros a display element can be adapted by gradual or stepwise adaptation of notably the column voltage values. The result of this adaptation is that the reduction in N_{max} which would otherwise occur due to the said voltage losses is considerably less. Since generally adaptation per column is more complicated (and hence costly) groups of column electrodes are preferably provided with substantially identical voltage levels. In practice the number of electrodes per group is determined by the available integrated LCD drivers.

The manner in which the voltage is varied across the various columns is also dependent on the drive mode. If the device is driven unilaterally, in other words, an associated row selection circuit supplies selection voltages only on one side of the liquid crystal matrix, then the highest data voltage is presented to the column(s) near the opposite side. In the case of bilateral drive the highest data voltage is presented substantially in the centre.

The described voltage compensation may of course also be used for the signals which are presented to the selection electrodes. Again dependent on the fact whether the data signals are presented unilaterally or bilaterally, the value of the selection voltage increases from the one side to the other side or from both sides to the centre.

The invention will now be described in greater detail with reference to some embodiments and the drawing in which

Fig. 1 diagrammatically shows in a cross-section a liquid crystal display device,

Fig. 2 is a diagrammatic representation of such a device in which the picture elements are arranged in accordance with a matrix, together with a part of the drive circuits,

Fig. 3 is a diagrammatic plan view of a row electrode,

Fig. 4 shows the relation between $\hat{V}_{on}$ and V_s for different electro-optical systems, while

Fig. 5 diagrammatically shows the structure of a drive circuit.

The display device shown in Fig. 1 has two glass support plates 1 and 2. The support plate 1 is provided with a pattern of strip-shaped row electrodes 3 consisting of, for example, indium tin oxide. The support plate 2 is also provided with a pattern of stripshaped column electrodes 4 consisting of, for example, indium tin oxide. The electrodes 3 cross the electrodes 4 and the crossings constitute the display elements which are thus arranged in accordance with a matrix. The surfaces of the support plates 1 and 2 provided with electrodes have orientation layers 6 and 7. A liquid crystal material 8 is present between the support plates. The distance between the plates is of the order of 10 μm which is maintained by spacers which are regularly distributed over the plate surfaces and are not shown in the drawing. A sealing edge 9 connects the support plates at their circumference. In this embodiment the support plates 1 and 2 are each provided with a linear polariser, namely a polariser 10 and an analyser 11, but this is not necessary. The display elements can be switched from a first condition to a optically different second condition by driving the electrodes 3 and 4 in a suitable manner.

Fig. 2 shows the drive principle of such a display device. A number of row electrodes 3 and a number of column electrodes 4 are shows which define a matrix of display element 12. The row electrodes 3 and the column electrodes 4 are provided with voltage pulses by a row scanning circuit 13 and a drive circuit 14, respectively, which are mutually synchronised by a connection 15.

According to the invention the voltage levels supplied by the drive circuit 14 are dependent on the column to be driven. This will be further explained hereinafter.

In the case of unilateral drive of the row electrode 3, for example, from the left-hand side in Fig. 3, the row voltage decreases from, for example, α V_s at point (a) to V_s at point (b), $\alpha > 1$. At the points (a), (b) it then holds for $\hat{V}_{on}$ and $\hat{V}_{off}$ for N rows that

$$\hat{V}^2_{on}\ (a) = \frac{1}{N}\,(\alpha V_s + V_D)^2 + \frac{N-1}{N}\ V^2_D \qquad \alpha > 1$$

$$\hat{V}^2_{off}\ (a) = \frac{1}{N}\,(\alpha V_s - V_D)^2 + \frac{N-1}{N}\ V^2_D$$

$$\hat{V}^2_{on}\ (b) = \frac{1}{N}\,(V_s + V_D)^2 + \frac{N-1}{N}\ V^2_D$$

$$\hat{V}^2_{off}\ (b) = \frac{1}{N}\,(V_s - V_D)^2 + \frac{N-1}{N}\ V^2_D$$

Since $\alpha > 1$, a smaller number is found for the maximum number of rows to be multiplexed than the number which is determined by the slope $S = \hat{V}_{on}/\hat{V}_{off}$ of the actual optical system, that is to say, the liquid crystal effect without any disturbing influences of electrical resistances in the row electrodes and possible other side effects.

For a number of values of α the number of rows to be multiplexed in systems with the same contrast as for multiplexing N_{max} with $\alpha = 1$ in systems with a slope S is shown in the Table below.

TABLE 1

	N_{max} = 64 (S_1)	N_{max} = 128 (S_2)	N_{max} = 256 (S_3)
	N	N	N
α = 1.02	55	104	194
α = 1.05	46	82	144
α = 1.10	36	62	101
α = 1.15	30	50	79
α = 1.25	23	37	56

Fig. 4 shows for a number of optical systems with α = 1 and N = 128 (S_2), N = 256 (S_3) and N = (S_4) the relations between

$$\frac{\hat{V}_{on}}{\hat{V}_{off}}$$

and

$$\frac{V_s}{\hat{V}_{off}}$$

derived from the equations:

$$\hat{V}^2_{on} = \frac{1}{N}(V_s + V_D)^2 + \frac{N-1}{N} V^2_D$$

$$\hat{V}^2_{off} = \frac{1}{N}(V_s - V_D)^2 + \frac{N-1}{N} V^2_D$$

and $$\hat{V}^2_{off} = V^2_{THR}$$

V_{THR}: threshold voltage of the optical effect. The maximum values in the curves S_2, S_3, S_4 correspond to the selection ratios $\hat{V}_{on}/\hat{V}_{off}$ in accordance with the drive mode as described by Alt & Pleshko. For an optical system with a threshold slope S_2 suitable for driving 256 rows the selection ratio (see Fig. 4) is approximately 1.065. If such an optical system is used in a matrix of 128 rows, it appears from Fig. 4 that there is a large region in which V_s/V_{off} and V_{on}/V_{off} are sufficient for driving, namely the region between the ordinates (i) and (ii). The associated selection ratio

$$\frac{\hat{V}_{on}}{\hat{V}_{off}}$$

is always ≥ 1.065.

Thus in this region a voltage drop from αV_s to V_s is permitted in a 128-row matrix with =

$$\frac{V_{Smax}}{V_{Smin}} .$$

In order to determine the number of rows to be multiplexed for α and S, we will return to the rms voltages $\hat{V}_{on}$ and $\hat{V}_{off}$ at the points (a), (b) in Fig. 3.

The notations D_1 and D_2 are used for the data voltages V_D (a) and V_D (b), respectively.

$$\text{(a)}\quad \hat{V}^2_{off} = \frac{1}{N}\,(\alpha V_s - D_1)^2 + \frac{N-1}{N}\,D^2_1 \qquad (1)$$

$$\text{(b)}\quad \hat{V}^2_{off} = \frac{1}{N}\,(V_s - D_2)^2 + \frac{N-1}{N}\,D^2_2 \qquad (2)$$

and the associated "on" voltages

$$\text{(a)}\quad \hat{V}^2_{on} = \frac{1}{N}\,(\alpha V_s + D_1)^2 + \frac{N-1}{N}\,D^2_1 \qquad (3)$$

$$\text{(b)}\quad \hat{V}^2_{on} = \frac{1}{N}\,(V_s + D_2)^2 + \frac{N-1}{N}\,D^2_2 \qquad (4)$$

(1) and (2) must be equal to each other. With $X = V_s/D_1$ and $Y = D_2/D_1$ this yields

$$\pm X = \frac{2(\alpha - Y) \pm \sqrt{4(\alpha - Y)^2 - 4N(1-Y^2)(\alpha^2 - 1)}}{2(\alpha^2 + 1)} \qquad (5)$$

Likewise it follows from (3) and (4) that

$$\pm X = \frac{-2(\alpha - Y) \pm \sqrt{4(\alpha - Y)^2 - 4N(1 - Y^2)(\alpha^2 - 1)}}{2(\alpha^2 + 1)} \qquad (6)$$

Since (5) and (6) are identical, it follows that

$Y = \frac{D_2}{D_1} = \alpha$ (7)

and

$X = \frac{V_s}{D_1} = \sqrt{N}$ (8)

For the selection ratio at point (a) it now holds that

$$\frac{\hat{V}^2_{on}(a)}{V^2_{off}(a)} = \frac{(\alpha V_s + D_1)^2 + (N-1)D^2_1}{(\alpha V_s - D_1)^2 + (N-1)D^2_1} \tag{9}$$

$$\text{with } \frac{V_2}{D_1} = \sqrt{N} \qquad S^2 = \frac{(\alpha^2+1)\sqrt{N} + 2\alpha}{(\alpha^2+1)\sqrt{N} - 2\alpha} \tag{10}$$

or

$$\sqrt{N} = \left(\frac{2\alpha}{\alpha^2+1}\right) \frac{S^2+1}{S^2-1} = \frac{2\alpha}{\alpha^2+1}\sqrt{N_{max}} \quad \text{and}$$

$$\frac{N}{N_{max}} = \left(\frac{2\alpha}{\alpha^2+1}\right)^2 \tag{11}$$

with (7) and (8) we find that for $V_s/V_d(a) = \sqrt{N}$ and $V_d(b) = \alpha V_d(a)$ the maximum number of rows that can be used is equal to

$$\left(\frac{2\alpha}{\alpha^2+1}\right)^2 N_{max}$$

This is shown in Table 2 below. The values of N are considerably higher than those in Table 1.

TABLE 2

	$N_{max} = 64$ (S_1)	$N_{max} = 128$ (S_2)	$N_{max} = 256$ (S_3)
	N	N	N
$\alpha = 1.10$	63	126	253
$\alpha = 1.15$	62	125	251
$\alpha = 1.25$	60	121	243
$\alpha = 1.40$	57	114	229
$\alpha = 1.50$	54	109	218

At a point (i) located between the points (a) and (b) the selection voltage is $\alpha_i V_s$ $(1 < \alpha_i < \alpha)$ and the data voltage $V_d(i)$ is then determined from
$(\alpha_i V_s - D_i)^2 + (N-1)(V_D(i))^2 = N \cdot V^2_{thr}$.
The resultant $\hat{V}_{on}$ voltage at the point (i) is then larger than that at the points (a), (b).

Fig. 5 diagrammatically shows a detail of a drive circuit with which these variable data voltages can be presented. To this end the drive circuit 14 of Fig. 2 is divided into sub-circuits 14^a, 14^b, ...14^n which are each connected via one or more outputs 16 to the column electrodes 4, while these sub-circuits are provided with synchronising signals and data signals through connection lines 15 and 27, respectively. In order to be able

to adjust the variable data voltage each sub-circuit 14^a, 14^b, ... 14^n is connected via a connection 18 to a variable resistor 19 which is present between two voltage lines 20, 21. The voltage values at these lines 20, 21 determine, together with the adjustment of the variable resistors 19, the various reference levels of the sub-circuits 14^a, 14^b, ...14^n and hence the voltage values of the column voltages at the outputs 16.

In the case of unilateral drive of the selection rows the voltage along the rows will decrease in one direction, for example, from the left to the right in Fig. 5. The compensation due to variation of the data voltage will then increase from the left to the right. In the case of simultaneous bilateral drive the compensation will be largest approximately in the centre of the row electrodes 3, in other words, the reference voltages for the sub-circuits 14^a, 14^b, ... 14^n are highest for the sub-circuits in or near the centre.

For the drive mode as described in patent application No. 11.868 simultaneously filed the reference voltages may decrease alternately from left to right nd from right to left. In the connections 18 of the variable resistors 19 an extra switch (not shown) is then incorporated with which the sub-circuits 14^a, 14^b .... 14^n can be alternately connected to two different variable connections of the resistors 19.

Similarly as described above for the data voltages the selection voltages can also be rendered variable in order to compensate for voltage losses due to resistance in the column electrodes 4. To this end the row scanning circuit 13 is divided in a manner analogous to the manner described above for the drive circuit 14 into sub-scanning circuits each connected to a different reference voltage. The compensation voltage presented via this reference voltage can increase in one direction (unilateral drive of the columns) or it can increase from the two ends to the centre (bilateral drive of the columns).

The invention is of course not limited to the embodiments described but several variations are possible within the scope of the invention. For example, if the losses across the row electrodes 3 are negligible, for example, when the number of colums is small with respect to the number of rows, the compensation can also be applied to the row selection voltages only. Also in this case the compensation can then be effected again per group of row electrodes.

Claims

1. A display device compising a liquid crystalline material between two parallel support plates having surfaces facing each other, a pattern of row electrodes being provided on the one surface and a pattern of column electrodes being provided on the other surface, the row electrodes crossing the column electrodes, thus constituting display elements at the area of the crossings, the device comprising a drive circuit for presenting data signals to be displayed to the column electrodes, and a row scanning circuit for scanning the row electrodes, characterized in that the drive circuit for a data signal to be displayed can present to a column electrode a voltage value dependent on the column electrode to be driven.

2. A display device as claimed in Claim 1, characterized in that the voltage values for a data signal to be displayed are substantially identical per group of column electrodes.

3. A display device as claimed in any one of the preceding Claims, characterized in that the device comprises a row scanning cicuit for periodically scanning the row electrodes by means of a selection voltage, the row electrodes being unilaterally driven from one side of the device and the voltage value associated with the data signals increasing in the direction of the other side.

4. A display device as claimed in any one of Claim 1 or 2, characterized in that the device comprises a row scanning circuit for periodically scanning the row electrodes by means of a selection voltage, the row electrodes being bilaterally driven and the voltage value associated with the data signals being maxium at the columns substantially in the centre between the two sides.

5. A display device comprising a liquid crystalline material between two parallel support plates having surfaces facing each other, a pattern of row electrodes being provided on the one surface and a pattern of column electrodes being provided on the other surface, the row electrodes crossing the column electrodes, thus constituting display elements at the area of the crossings, the device comprising a drive circuit for presenting data signals to be displayed to the column electrodes and a row scanning circuit for presenting row selection signals to the row electrodes, characterized in that the row scanning circuit for a selection pulse can present to a row electrode a voltage value dependent on the row electrode to be driven.

6. A display device as claimed in Claim 5, characterized in that the voltage values of the selection pulses are substantially identical per group of row electrodes.

7. A display device as claimed in one or more of Claims 1 to 6, characterized in that the data signals are presented from one side and the value of the selection voltage increases in the direction of the other side.

8. A dfisplay device as claimed in one or more of Claims 1 to 6, characterized in that the data signals are presented bilaterally and the value of the selection voltage is substantially maximum at the row electrodes substantially in the centre between the sides.

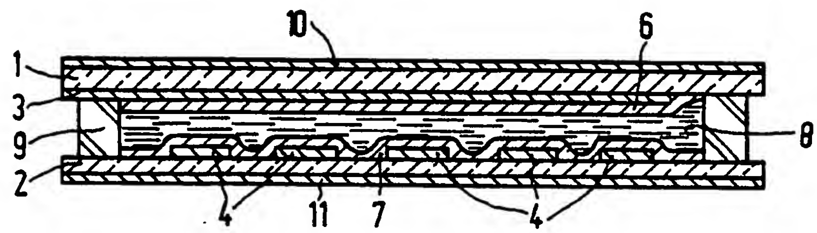


FIG. 1

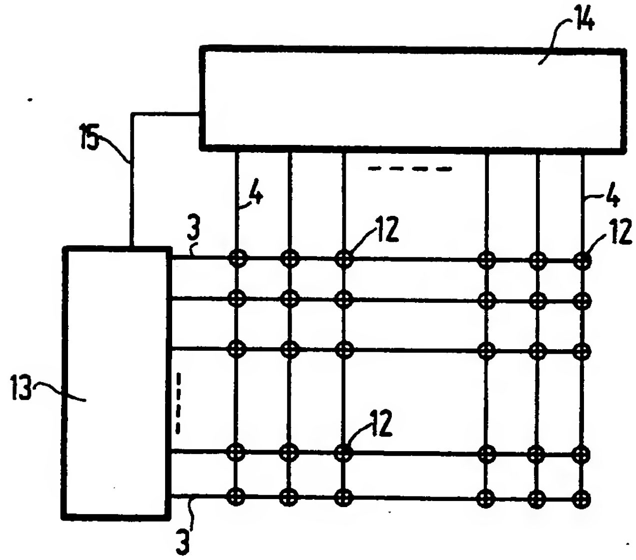


FIG. 2

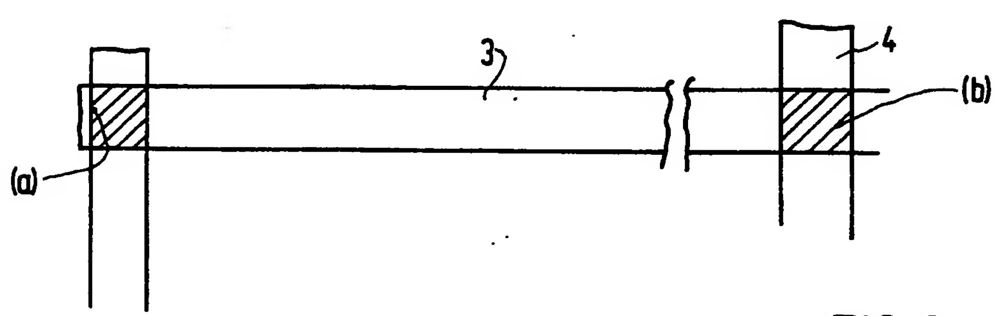


FIG. 3

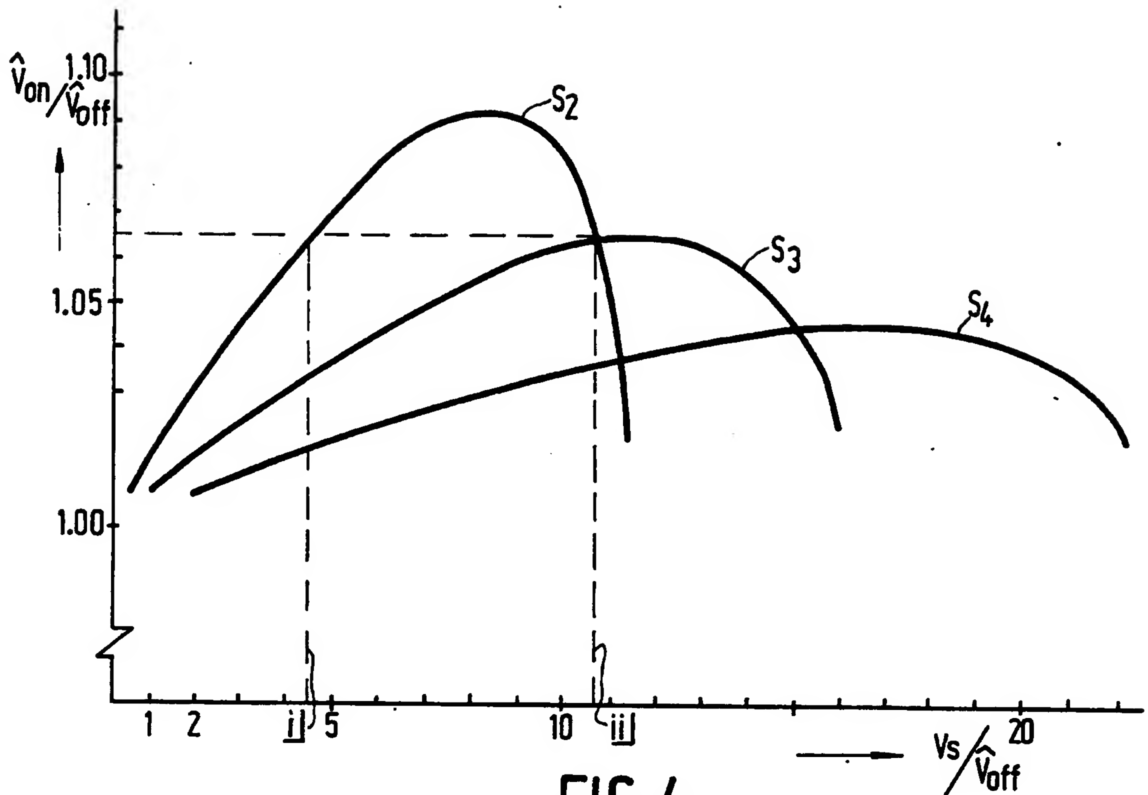
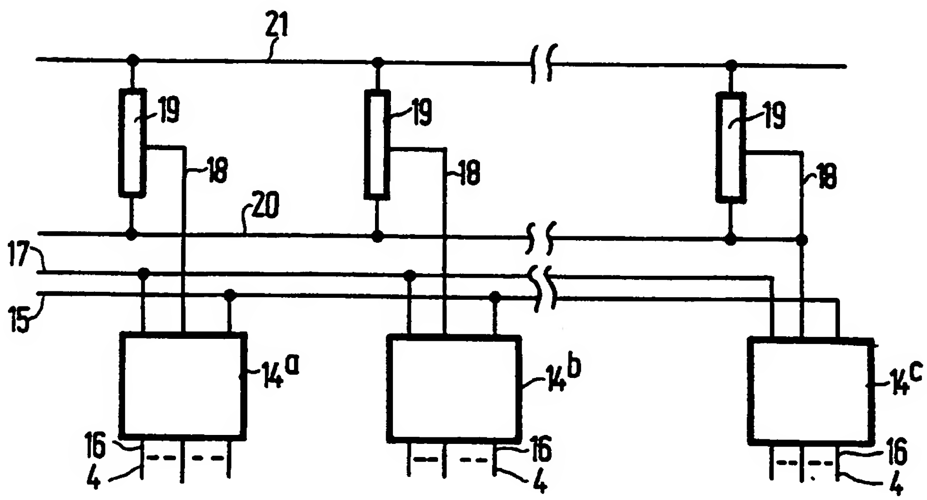

$\hat{V}_{on}/\hat{V}_{off}$
1.10
1.05
1.00
S2
S3
S4
1
2
i
5
10
ii
20
$Vs/\hat{V}_{off}$

FIG. 4


21
19
18
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17
15
14a
14b
14c
16
4

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number

EP 87 20 1716

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE-A-2 752 602 (BBC AG BROWN, BOVERI & CIE.) * Figures 1,2; page 17, line 7 - page 21, line 7 * -----	1	G 09 G 3/36
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			G 09 G H 04 N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17-12-1987	VAN ROOST L.L.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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